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MESSENGER Observations of Magnetic Flux Ropes in Mercury's Plasma Sheet

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MESSENGER orbital observations provide a new opportunity to investigate magnetic reconnection in the cross-tail current sheet of Mercury's magnetotail. Here we use measurements collected by the Magnetometer and Fast Imaging Plasma Spectrometer (FIPS) during "hot seasons," when the orbital periapsis is on Mercury's dayside and MESSENGER crosses the plasma sheet at distances of $\sim$1.5 to 3 R_M (where R_M is Mercury's radius, or 2440 km). These data frequently contain signatures of large-scale magnetic reconnection in the form of plasmoid-type magnetic flux ropes and southward magnetic fields in the post-plasmoid plasma sheet. In the cross-tail current sheet, which separates the north and south lobes of the magnetotail, flux ropes are formed by reconnection at two or more X-lines and are then transported either toward or away from the planet by the Alfvénic flow emanating from the X-lines. Here we present a survey of 49 plasmoid-type flux ropes identified during seven MESSENGER "hot seasons," for which minimum variance analysis indicates that the spacecraft passed near the central axis of the structure. The locations of the selected flux ropes range between 1.7 and 2.8 R_M down the tail from the center of the planet. With FIPS measurements, we determined an average proton density of 2.55 cm^{-3} in the adjacent plasma sheet surrounding the flux ropes, implying an Alfvén speed of $\sim$450 km s^{-1}. Under the assumption that the flux ropes are moving at the local Alfvén speed, we used the mean duration of 0.74 $\pm$ 0.15 s to calculate a typical diameter of $\sim$0.14 R_M, or $\sim$340 km. We have modeled the plasmoids as force-free flux ropes in order to confirm this result. A superposed epoch analysis demonstrates that the magnetic structure of the flux ropes is similar to what is observed at Earth, but the timescales are 40 times faster at Mercury. The results of this flux rope survey indicate that intense magnetic reconnection occurs frequently in the cross-tail current layer of this small but extremely dynamic magnetosphere.